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TECHNICAL NOTE

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MEASUREMENTS FOR SPACE NAVIGATION

THE EFFECT OF FIELD OF VIEW ON
STAR FIELD IDENTIFICATION

By Daniel M. Hegarty

PRELIMINARY MEASUREMENTS OF THE ACCURACY OF
MANUAL OPTICAL SIGHTING AT THE CENTER OF
A PLANETARY DISK

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TWO SIGHTING PROBLEMS ASSOCIATED WITH SEXTANT TYPE MEASUREMENTS FOR SPACE NAVIGATION

SUMMARY

Tests were made to determine how the time of identification of a star field depends upon the field of view of the area to be identified. These preliminary results are directly relevant to the use of remote TV for monitoring the pointing direction of a satellite and indicate the field of view required by the ground operator.

The accuracy to which an observer can estimate the center of a planetary disk with a theodolite was measured. The effects of theodolite reticle design, shape of visible portion of disk (elliptical or crescent), and motion of target and observer were considered. The results are presented in statistical terminology associated with the normal (or Gaussian) distribution.

THE EFFECT OF FIELD OF VIEW ON STAR FIELD IDENTIFICATION

By Daniel M. Hegarty

PROCEDURE

A study was first made with information presented on slides. In essence, a man was presented with both a map of a constellation, in the form of a projected slide (four constellations were used as reference areas; they were Andromeda, Cepheus, Cassiopeia, and Cygnus) and a series of test areas to be identified. These test areas were small segments of the reference constellation. Identifying the test area consisted of pointing, with a flashlight pointer, to the particular star or group of stars in the reference area. The time necessary for the subject to correctly identify the area was recorded. An arbitrary time limit of 7 minutes was set for each identification.

In the second part of the study, the reference constellations were projected on a screen but the test areas were presented on a closed-circuit TV monitor. Both parts of the study were made with six subjects. Four of the subjects were used in both parts of the study; one with a background in astronomy was included in the group which took both tests. Although the same slides and some of the same subjects were used in both test methods, it is felt that, since the two parts were performed approximately one year apart, there was no appreciable bias in the second part of the study.

The scope of the study was limited; therefore, care should be used in extending the results to actual star field identification because the slides did not have uniform resolution and the stellar areas used as references were small compared to the entire heavens, being approximately $22^\circ \times 28^\circ$

In the slide projector test the size of the reference constellation was 52 by 40 inches and in the TV monitor test, 60 by 45 inches; the size of the test area was 19.5 by 19.5 inches and 12.5 by 12.5 inches, respectively. The subject was approximately 11 feet from the presentation for the slide projector test but only about 7 feet for the TV monitor test.

A reference constellation was presented to the subject as a projected slide. Then the test areas, smaller than but included in the reference constellation, were presented one at a time for identification. An arbitrary time limit of 7 minutes was set for the identification. Each new reference constellation was projected for a period of approximately one minute for the subject to study before the next test area was presented. The test areas were presented to each subject in the following order: $15^\circ \times 15^\circ$, $10^\circ \times 10^\circ$, $5^\circ \times 5^\circ$, and $2^\circ \times 2^\circ$. The test periods were adequately spaced to avoid the effect of eye fatigue on the results. The data recorded included not only the identification time for each test area for each subject but also the identification numbers and the orientation of the test area slide.

RESULTS

Figure 1 is a comparison of the median identification times obtained by the two test methods. Each plotted point represents, on an average, 120 samples. It is the author's opinion that the shorter distance of the reference constellation from the subject was an advantage in the TV monitor test method and was a primary source of the difference in the identification times for the two smaller field of view angles. For the two larger size view angles, the TV presentation had a loss of fidelity which counteracted the advantage of the shorter distance to the reference constellation and the median times are about the same for both methods.

There does seem to be some correlation between the orientation of the test area and the required identification time. The difference between the identification times for the upside down and the right side up test areas increased as the field of view increased. Since the orientation of the test area is random with respect to the reference area, the subject must search with this in mind. The smaller the test area, the fewer stars it will contain, in general; thus the patterns which the subject will choose to match with the reference area will naturally be simplified for the smaller test areas. This chosen pattern becomes more complicated as the test area increases in size and causes the orientation of the test area with respect to the reference area to become more important.

A study of the data revealed that, in general, the identification times for various test areas vary considerably from subject to subject. For example, one typical $2^{\circ} \times 2^{\circ}$ test area was identified in times ranging from 18 seconds to 2.5 minutes. Some test areas were identified in less than 30 seconds by all six subjects and one test area, in the slide projector test method, was not identified by any of the six subjects.

The study showed that one of the most important factors in the identification is the "easily recognizable" patterns in the area to be identified. If the area contains these patterns then the identification is much easier than if there are no such patterns. These patterns are subjective, but consist mainly of star position and magnitude combinations which the subject can carry in his mind for comparison with the reference area.

The present study was conducted mainly with people inexperienced in stellar recognition and it is expected that the identification times would be reduced if the subjects were experienced in stellar recognition.

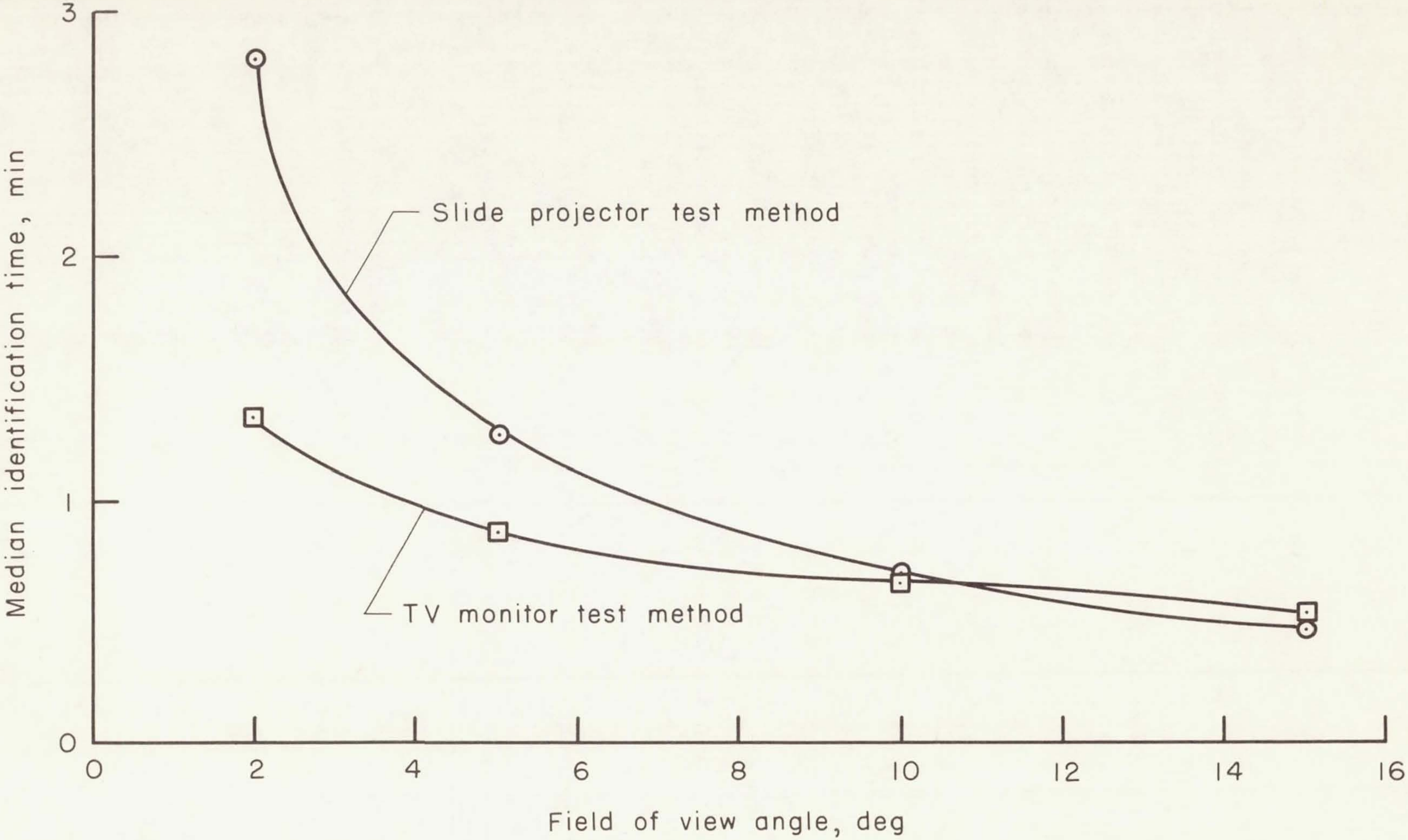

Figure 1.- Median identification time versus field of view angle.

PRELIMINARY MEASUREMENTS OF THE ACCURACY OF

MANUAL OPTICAL SIGHTING AT THE CENTER OF

A PLANETARY DISK

By Marvin H. Thigpen

EXPERIMENTAL PROCEDURE

Measurements were made with a surveying theodolite having a magnification of 28 and a field of view of 1.5°. The reticle patterns used for the measurements were of two types, (a) cross hairs and (b) cross hairs with concentric circles centered at the intersection of the cross hairs. Four types of targets were used in this investigation: (1) a black circle scribed on a white background, (2) a white circular disk on a dark background, (3) white crescents on a dark background, and (4) a white elliptical disk with an eccentricity of 0.08 on a dark background. Three conditions were investigated: (1) stationary target and observer, (2) stationary target with the observer oscillating in azimuth at frequencies of 0.01, 0.03, and 0.10 cycles per second, and (3) target moving at rates of 1.5, 9.0, and 15 seconds of arc per second in azimuth and elevation with the observer stationary.

For the measurements with stationary target and observer, the theodolite was placed in a steel structure suspended from the ceiling and the circle target was mounted on a plate fastened to the wall of the laboratory. The circle was about 30 feet from the theodolite and had an apparent diameter of 0.5°. An attempt was made to determine any loss in accuracy which might result from the motion of an observer sitting on an oscillating platform. The platform used for oscillating the observer consisted of a modified 60-inch searchlight system driven by a low-frequency function generator. Three frequencies were used; 0.01, 0.03, and 0.10 cycles per second. Although the input signal was sinusoidal, the output motion was somewhat irregular having a peak-to-peak amplitude of 4°.

In a third series of tests the circular-disk target was moved at rates of 1.5, 9.0, and 15.0 seconds of arc per second. The target was mounted on a modified height gage which was equipped to operate as a rate servo. The observer set the theodolite elevation control to a position ahead of the target and then tracked the target with the azimuth control until the target edge appeared concentric with the reticle pattern.

RESULTS

Results for the stationary target and observer (table I) indicate an improvement of 2 to 4 seconds of arc in standard deviation when a reticle having a pattern of concentric circles and cross hairs rather than cross hairs alone is used to estimate the center of the target. An eccentricity of 0.08 in the target

shape did not seem to affect the measurements. The results for a thin crescent indicate a loss of about 1 second of arc compared to the results for a fully visible circular-disk target. A thick crescent cannot be centered by the concentric circle reticle as precisely as the thin crescent. About 2 seconds of arc loss in precision resulted when the thick crescent was substituted for the thin crescent.

Motion of the observer at the three frequencies used did not seem to contribute any error, the results in table II being similar to those obtained by the same observers on a circle target with the observer not moving (table I).

The moving target data in table III indicate a deterioration of precision with increasing target speed. At the highest rate used (15 seconds of arc per second) the standard deviation was 9 seconds of arc. From a practical standpoint this precision is poor for an instrument with such good static precision.

The precision data presented are as stated for 28 power telescope optics with a 1-1/2° field of view. Apparent target size and apparent target speed will be a function of the power of the optics used so any extrapolation of this data to cislunar problems must reflect the power of the optics contemplated.

Ames Research Center
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TABLE I.- STATIONARY TARGETS AND STATIONARY OBSERVERS

Observer	Reticle	Target	Number of measurements	Standard deviation azimuth, sec arc	Standard deviation elevation, sec arc
I	Cross hair	Circle	100	5.4	9.5
I	0.2	Circle	100	1.9	2.6
II	.2	Circle	100	3.1	3.1
III	.1	Circular disk	50	1.2	1.7
III	.1	Elliptical disk e = 0.08	75	1.2	1.3
III	.1	Thin crescent	50	2.3	2.8
I	.1	Thick crescent	100	5.4	5.6
III	.1	Thick crescent	72	4.0	3.4

Note: Reticles 0.2 and 0.1 had circles spaced 0.2° and 0.1°, respectively.
The thin crescent had a maximum thickness of 1 minute of arc.
The thick crescent had a maximum thickness of 9 minutes of arc.

TABLE II.- STATIONARY TARGETS AND OSCILLATING OBSERVERS

Observer	Frequency, cps	Number of measurements	Standard deviation azimuth, sec arc	Standard deviation elevation, sec arc
I	0.01	100	2.0	2.2
	.03	100	2.5	2.5
	.10	100	1.8	1.8
II	.01	105	2.9	2.7
	.03	100	2.9	3.2
	.10	108	2.9	2.1

Note: Reticle with 0.2° circle spacing was used.
Circle target was used (0.5° subtense).
Amplitude of oscillation was 4° peak to peak.

TABLE III.- MOVING TARGET AND STATIONARY OBSERVER

Observer	Rate, sec of arc/sec	Number of measurements	Standard deviation azimuth, sec arc	Standard deviation elevation, sec arc
I	1.5	60	3.3	2.2
	9.0	60	5.5	5.4
	15.0	60	9.0	5.0

Note: Reticle with 0.1° circle spacing was used.
Circular disk target was used.

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